Part Number: 99-0550

Revision History:

Rev	Rev Date	Modified by	Description
A	9/28/2018	CC/NAW	First Release
B	1/23/2019	CC	Changed part number on page 1 to 99-0550
C	6/20/2019	CC	Added and modified CAN messages. Added “Auto-Baud”.
D	6/25/2019	CC	Added accelerometer angle message and serial number capability.
E	8/27/2017	CC	Changed PGN on the proprietary ‘Device CAN Messages’. Updated factory zero, calibration, stored settings, and device settings command messages. Added stored offset message. Updated environmental specifications.
F	9/12/2019	CC	Added accelerometer calibration command and made calibrated acceleration part of the data request. Added device settings and commands to system blocks and features. Added mounting configurations.
G	10/2/2019	CC	Updated overview and specifications,
H	10/2/2019	NAW	Remove preliminary watermark, first release for distribution.

Contents

Project Overview & Description

The gyro-compensated inclinometer, referred to as 'the device', transmit its relative angle over a CAN network. This device offers advantages over standard MEMS inclinometers by helping to filter out sources of inaccuracy, such as vibration and shock of an operating vehicle.

Angle Sensor:

- Transmission of +/-64 degrees Pitch and Roll data using standard J1939 PGN (depending on model).
- Transmission of +/-180 degrees 'Blade Angle' data using standard J1939 PGN (depending on model).
- Two on board gyro-compensated angle sensors for redundancy and enhanced accuracy.
- Updated sensor data every 10 millisecond (100Hz).
- User programmable transmit rate to allow for reduced bus traffic.
- Adjustable filtering for faster response or better noise filtering.
- Entirely Solid-State Design (MEMS).

Standard Features:

- User configurable mounting orientation, zero-axis, polarity, sensitivity.
- User configurable CAN Address allows for multiple devices on the CAN bus.
- Auto baud rate detection for 125kbd, 250kbd, 500kbd, and 1000kbd.
- Internal non-volatile memory used to save user settings.
- Poka-Yoke mounting feet to prevent assembly errors.

Additional Features:

- A single device can be used for both single and dual axis sensing requirements.
- Transmission of raw accelerometer and gyroscope data using proprietary PGN.
- Transmission of sensor temperature using proprietary PGN.

Environmental Features:

- Wide operational voltage range works on both 12VDC and 24VDC systems.
- Ruggedized for Industrial & Automotive environments.
- Enhanced immunity to error caused by vibration and shock.
- Ingress Protection to IP67 Rating.
- 48V Jump Start compliant.
- Load Dump compliant.
- Protected against reverse battery.

Other variants available:

- Lower cost single sensor option available.
- Additional pitch and roll range of up to +/-180 degrees with proprietary J1939 PGN.
- Two spare inputs available for addressing using harnessing or peripheral input.
- Custom defaults, firmware, and other features upon customer request.
- Internal CAN bus termination resistor option.

Operation

General Operation

At power up, the device will detect the baud rate of the CAN network. It does this by cycling through the available baud rates until it sees communication on the bus. Note: the device requires two active fixed baud rate devices communicating on the bus to detect the baud rate.

Once the baud rate is detected, the device will begin transmitting the angle of each of the sensors. These messages are transmitted continuously on the CAN bus. Each sensor transmits from its own customizable source addresses.

Sensor 1 is assigned address 0xE2 by default. Sensor 2 is assigned address 0xE3 by default. The average reading between sensors 1 and 2, called the compensated sensor data, is transmitted under address 0xEA by default.

When the device has power, the green 'PWR' LED will turn on.

When the device is communicating on the CAN bus, the red 'CAN' LED will flash. If the unit has lost communication to the CAN bus, the red indicator LED will stay on.

Operational Variants

There are different variants of this device. These device's vary on which mode they can operate in. The available modes are:

- Dual-Axis Mode
- Single-Axis Mode

Dual-Axis Mode Operation

The device can be used in 'Dual-Axis' mode to measure pitch and roll. This is commonly used to measure the angle of a vehicle for leveling and safety. This mode can be used in a variety of applications.

Single-Axis Mode Operation

The device can be used in 'Single-Axis' mode to measure the blade angle. This is commonly used to measure the angle of an item attached to a vehicle, such as a ladder, boom, or bucket. This mode can be used in a variety of applications.

Connector Specifications

The connector is used to connect power and the CAN bus.

Connector Pinout

Pin	Name	Details
1	CAN_H	CAN High
2	CAN_L	CAN Low
3	Ground	(Battery/Power Return, Negative)
4	Battery/Power Input	+Battery (12/24V Nominal)
5	Input 1	Not Implemented on Standard Product (Option)
6	Input 2	Not Implemented on Standard Product (Option)

Mating Connectors

Recommended

Type	Part Number	Manufacturer
Mating Connector	0934454101	Molex
Mating Contact	0936410012 or 0845250009	Molex
Mating Wedgelock	0934484003	Molex

Alternate

Type	Part Number	Manufacturer
Mating Connector	DT06-6S	Deutsch
Mating Contact	0462-201-16141	Deutsch
Mating Wedgelock	W6S	Deutsch

Electrical Specifications

Parameter	Min	Typ.	Max	Units	Notes
Functional Battery Voltage	8	14	45	VDC	Continuous
Jump Start Voltage			48	VDC	No Time Limit
Reverse Battery Voltage	-	-	-45	VDC	No Time Limit
Current Consumption	8.5	-	16.5	mA	14VDC, 250K Baud
Electrostatic Discharge (ESD)	-15	-	15	KV	Per SAE J1113-13/J1455 Section 4.13.2.2.3

Environmental/Mechanical Specifications

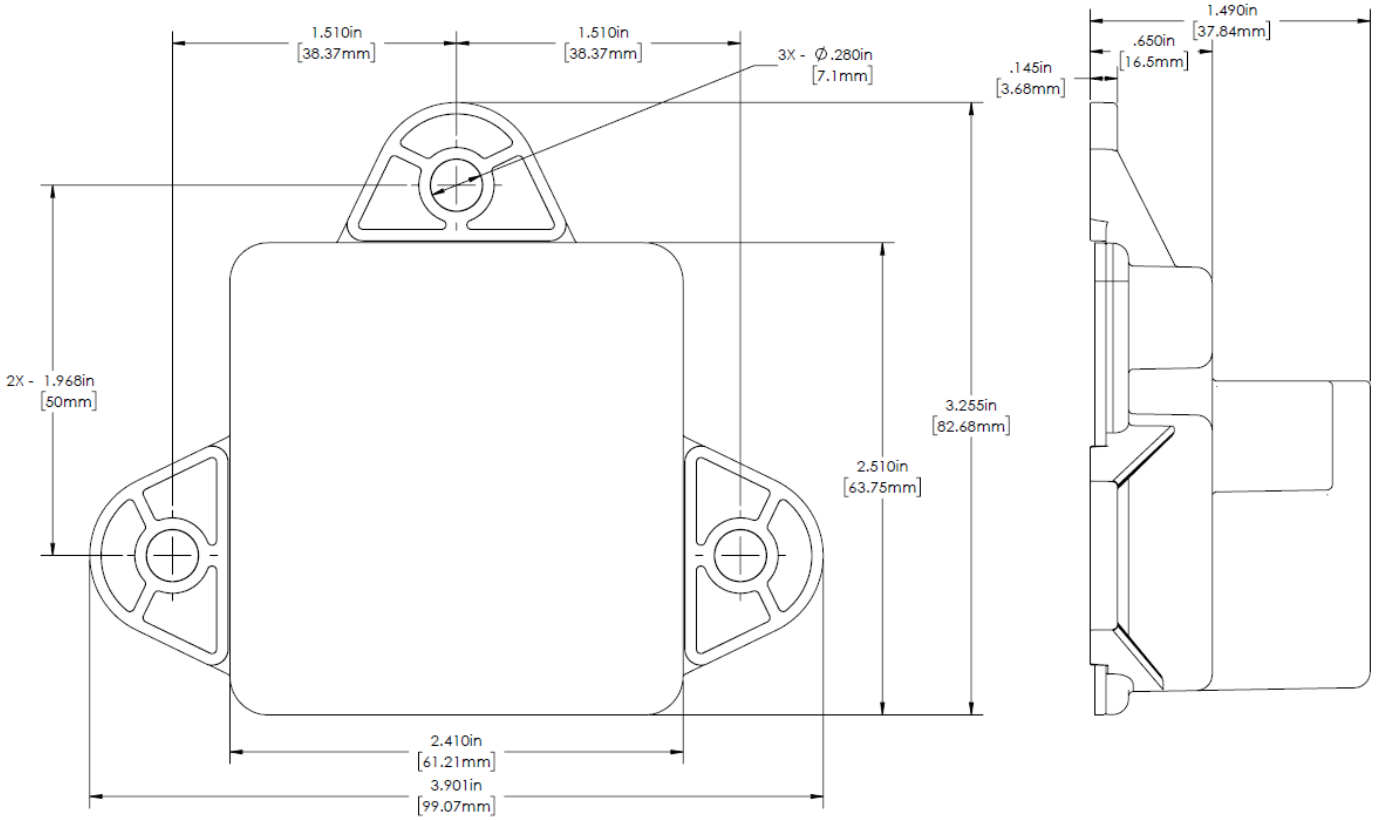
Parameter	Min	Typ.	Max	Units	Notes
Storage / Operating Temperature	-40	-	85	C	ISO16750-4, Sections 5.1.1.1, 5.1.1.2, 5.1.2.2, and 5.1.2.2.
Mechanical Shock-Operational			50	g	
Mounting Torque	15		30	In-lbs	May vary based upon customer hardware, tested with M6 hex head bolt, split lock washer, and flat washer. Damage may occur if torqued above max without insert present.

Parameter	Test	Notes
Thermal Cycle Test	SAE J1455 Section 4.1.3 8-Hour Cycle	Powered, -40C to 85C, 100 cycles
Thermal Shock Test	ISO16750-4 Section 5.3.2	-40C to 85C, 100 cycles, 60 min dwells, unpowered
Drop Test / Handling Shock	IEC 60068-2-31 Section 5.1, 5.2.	Topple, Free Fall 1m onto concrete.
Humidity & Temperature Cycling (Thermal Cyclic Aging)	SAE J1455 Section 4.2.3, Figure 4A, 8 Hour	Powered but not necessarily monitored for function. -45C to 90C, 100 cycles
Fluid Compatibility	SAE J1455 Section 4. 4	Degreaser, DEF, Diesel, 10W-30 Motor Oil, Anti-Freeze
Thermal Shock Immersion	ISO16750-4 Section 5.4.3	85C to Ice Water, Salt, Detergent, Dye, Unpowered for dunk. Tested powered after.
Ingress Protection (IP)	IEC 60519, IP67	1m of Water, 30 minutes. Water and equipment temperature within 5C of each other.
Vibration - Sinusoidal	10-22.289Hz 10mm P-P Displacement, 22.289Hz to 500Hz, 20g RMS acceleration.	Sweep rate 1 oct/min, X, Y, Z Axes, 20 cycles on each axis.
Vibration - Random	Trombetta profile, 11.55G RMS, 5-2000Hz	6 units, 2 per axis, 3 axes.
Load Dump	ISO16750-2, Section 4.6.4.2.1, SAE J1113-11, Pulse 5A, ISO7637 Pulse 5A	Without Centralized Suppression, Us = 174V, Ri = 1ohm, td = 350ms, tr = 10ms, 10 pulses

Sensor Specifications

Parameter	Min	Typical	Max	Unit	Notes
Dynamic Angle Accuracy		0.25	0.5	Deg	+/-45 degree range
Static Angle Accuracy		0.1	0.3	Deg	+/-45 degree range
Angle Accuracy with Temperature		0.1		Deg	
Pitch/Roll Angle Resolution		0.002			
Blade Angle Resolution		0.0078125			
Sensor Drift			0.1	deg	
Sensor Output Data Rate		1.66		kHz	Sensor read rate, TX rate on CAN is 100Hz
Accelerometer Scale	-2		+2	g	
Gyroscope Scale	-1000		+1000	dps	
Dual-Axis Angular Range	-64		+64.5	deg	Custom options with non-standard PGN/SPN's available with larger range.
Single-Axis Angular Range	-180		+180	deg	
Linearity, best fit straight line	-2		+2	%	
Sensitivity, based on 12-bit resolution		204		LSB/deg	
Repeatability	-2		+2	%	
Absolute Level Pitch Value		0		deg	
Absolute Level Roll Value		0		deg	
Absolute Level Blade Value		0		deg	

Mechanical Requirements



Dimensions are for reference.

System Blocks and Features

MEMS Sensors

The device has two microelectromechanical systems (MEMS) sensors that include both a 3D accelerometer and a 3D gyroscope.

Each of these sensors are used to determine the current pitch and roll angle of the device. Each of the sensor's measurements are transmitted as either 'Slope Sensor Information' messages or 'Blade Angle' on the CAN bus.

A third virtual sensor's message is also sent on the bus. This message, called the compensated sensor data, is the average reading between the two sensors. However, the data is only averaged together if the measurements are within ten degrees of each other. This is done to reject noise spikes.

LED Indicators

The device has two indicator LEDs. The 'Power' indicator (PWR), and the 'Communication' indicator (CAN). These are used to inform the user of the status of the device.

Power Indicator

The power indicator LED informs the user that the unit has battery power and is running. The power indicator LED is green. It is controlled by the microcontroller. The states of the power indicator are:

- Off System is not operational.
- On System has battery power and is operational.

Communication Indicator

The communication indicator LED informs the user of the CAN communication status. The communication indicator LED is red. The states of the communication indicator are:

- On Communication with the CAN bus has been lost.
- Flashing Communication with the CAN bus is active.

The communication indicator should never be in the off state.

Standard Available Data

The device can transmit the following data (In addition to the gyro-compensated angle):

- Serial Number
- Software Revision
- Stored Settings
- Stored Offsets

All standard available data can be requested using the 'Data Request Command' message.

Serial Number

The serial number of the device. This value is set at the factory.

Software Revision

The software revision of the device. This value is set at the factory.

Stored Settings

The stored settings are all of the settings set by the user. The user can request the status of the settings directly from the device.

Stored Offsets

The stored offsets are both the manual user offsets, and the zero offset. The user can request the stored offsets directly from the device.

Additional Available Data

Certain models can also access the following data:

- Raw Acceleration
- Calibrated Acceleration
- Raw Gyroscope
- Accelerometer Angle
- Temperature

All additional available data can be requested using the 'Data Request Command' message.

Raw Acceleration

The raw acceleration data is the linear acceleration data read directly from the MEMs sensor. This includes data in the x, y, and z axis.

Calibrated Acceleration

The calibrated acceleration data is the linear acceleration data that has been calibrated after it was read from the MEMs sensor. This includes data along the x, y, and z axis.

Raw Gyroscope

The raw gyroscope is the angular acceleration data read directly from the MEMs sensor. This includes data about the pitch, roll, and yaw axis.

Accelerometer Angle

The accelerometer angle is the angle calculated using only the accelerometer data.

Temperature

The temperature is the temperature data read directly from the MEMs sensor.

Device Settings

The following settings can be set by the user:

- Node Address
- Sensors Transmitted
- Sensor Data Transmit Interval
- Angle Sample Size
- User Offset
- Axis Mode

- Angle Polarity
- Pitch and Roll Orientation
- Mounting Orientation
- Vibration Filter
- Rate of Angle Change

Note: The device must be in service mode to change any of the settings.

Node Address

The 'node address' is the CAN source address of each of the on-board sensors. The default addresses are:

- 0xE2 Sensor 1
- 0xE3 Sensor 2
- 0xEA Compensated Sensor Data

The node address for each of the sensors can be set using the 'Set Sensor Address' message. The address change will be saved to non-volatile memory. This can be set in the 'Sensor Address Command' message.

Sensors Transmitted

The 'sensors transmitted' sets which sensors are transmitting the 'Slope Sensor Information' message. This allows the user to turn off any sensors they do not want to receive data from to reduce traffic on the CAN bus. The user can set the device to:

- Transmit all data (sensor data and compensated data)
- Transmit only the compensated sensor data
- Transmit only the sensor data
- Transmit data from only a single sensor

This can be set in the 'Device Settings Command' message by changing the 'Sensor Data Transmitted' setting.

Sensor Data Transmit Interval

The 'sensor data transmit interval' sets how often the 'Slope Sensor Information' message and the 'Blade Information' message is sent. The default is every 10ms. This can be set in the 'Device Settings Command' message by changing the 'Transmit Interval' setting.

Angle Sample Size

The sample size sets how many samples of the angle data are averaged to get the angle data transmitted to the user. The default sample size is 20. This can be set in the 'Device Settings Command' message by changing the 'Sample Size' setting.

User Offsets

The user offsets allow the user to manually set the pitch, roll, and blade angle. This can be set in the 'Sensor Offset Adjustment Command' message.

Axis Mode

The axis mode will set the device to operate in either single axis mode (blade angle) or dual axis mode (pitch and roll angle). Note: This can only be set on certain versions of the device.

In single axis mode, the device will transmit the 'Blade Information' message. In dual axis mode, the device will transmit the 'Slope Sensor Information' message. This can be set in the 'Device Settings Command' message by changing the 'Axis Mode' setting.

Angle Polarity

The angle polarity allows the user to set the polarity of the transmitted angle. This will allow the user to have the polarity of the angle match the rotation of the desired mounting position. This can be set in the 'Device Settings Command' message by changing the 'Pitch Polarity' and 'Roll Polarity' setting.

Pitch and Roll Orientation

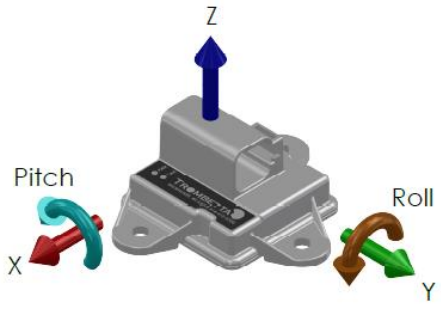
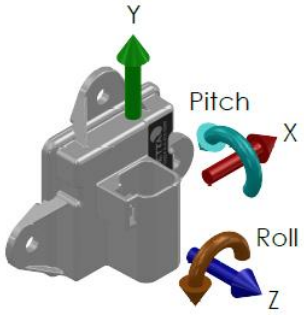
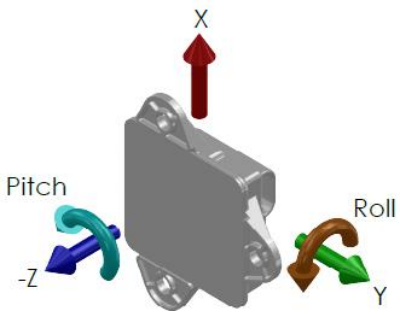
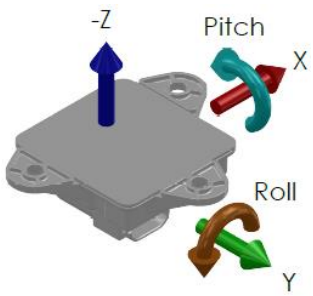
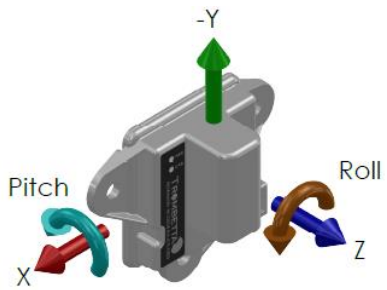
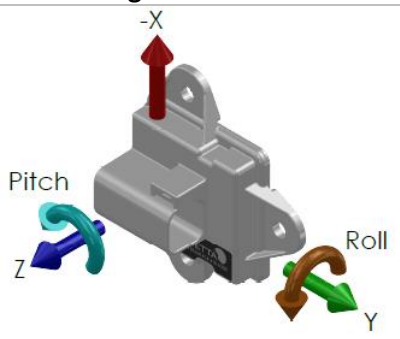
The pitch and roll orientation will allow the user to switch the reported pitch and roll data (i.e. pitch will be reported as roll, and roll will be reported as pitch). This will allow the pitch and roll data to match the desired mounting position. This can be set in the 'Device Settings Command' message by changing the 'Pitch and Roll Orientation' setting.

Mounting Orientation

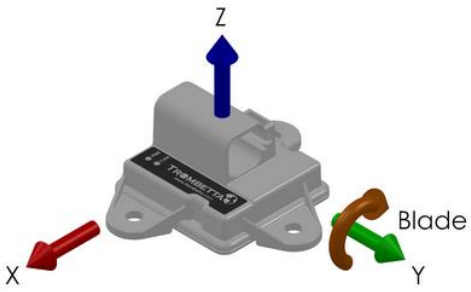
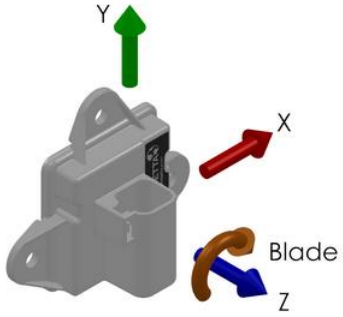
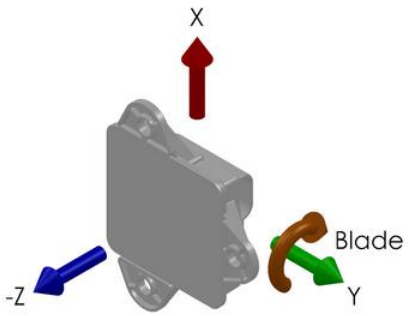
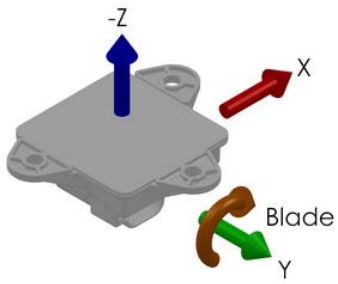
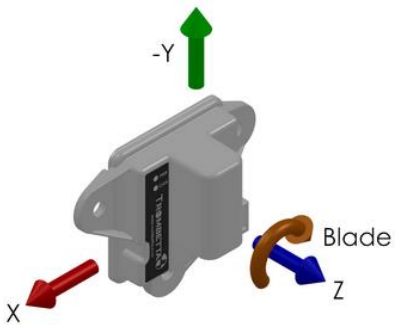
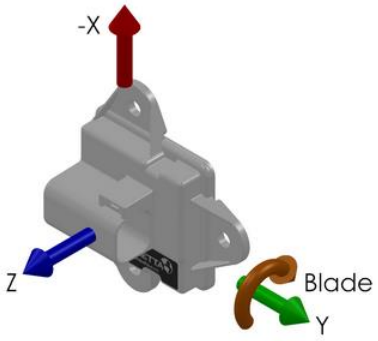
The device is capable of being mounted in all six mounting orientations. The mounting orientation is based on which axis is vertical to the ground (Vertical Plane). This can be set in the 'Device Settings Command' message by changing the 'Vertical Plane' setting. The mounting configurations are labelled as:

- Z-Plane
- Y-Plane
- X-Plane
- Negative Z-Plane
- Negative Y-Plane
- Negative X-Plane

Pitch and Roll Angles Mounting Orientation

Z-Plane	Y-Plane	X-Plane
		
Negative Z-Plane	**Negative Y-Plane**	**Negative X-Plane**
		

Blade Angle Mounting Orientation

Z-Plane	Y-Plane	X-Plane
		
Negative Z-Plane	**Negative Y-Plane**	**Negative X-Plane**
		

Vibration Filter

The vibration filter allows the user to determine how they want to filter vibration. The available settings are:

- Low Noise Mode
- Noise Block Mode

In low noise mode, the device will slow down the rate of angle change when noise is detected. In noise block mode, the device will reject any angle changes when noise is detected. This can be set in the 'Device Settings Command' message by changing the 'Vibe Filter' setting.

Rate of Angle Change

The rate of angle change sets the speed of the angle change. This allows the user to set the angle change for either faster speed or better noise rejection. This can be set in the 'Device Settings Command' message by changing the 'Acc Increment' setting.

User Commands

The following commands can be sent by the user:

- Service Mode Command
- Auto-Zero Sensors Command
- Auto-Detect Mounting Orientation Command
- Clear Manual Offset Command
- Clear Zero Offset

Note: Except for service mode, the device must be in service mode to accept any commands.

Service Mode Command

The service mode command will put the device in service mode. This mode allows the user to change the device settings. This can be set using the 'Service Mode Enable' message.

Auto-Zero Sensors Command

The zero sensors command will make the device set its' current position as zero (i.e. pitch and roll become zero). This can be set in the 'Device Settings Command' message using the 'Zero Sensors' setting.

Auto Detect Mounting Orientation Command

The detect mounting orientation command will make the device automatically detect its' mounting orientation. It does this by determining which axis is most perpendicular to the ground. This can be set in the 'Device Settings Command' message using the 'Detect Vertical Plane' setting.

Clear Manual Offset Command

The clear manual offset command will clear the user offsets. This can be set in the 'Device Settings Command' message using the 'Clear Offset Adjustment' setting.

Clear Zero Offset Command

The clear zero offset command will clear the zero offset the was set in the 'Zero Sensors' command. This can be set in the 'Device Settings Command' message using the 'Clear Zero Offset' setting.

CAN Communication

This device communicates on a J1939 CAN network. It will automatically detect the baud rate at power up. It will operate on a CAN bus running at 125kb, 250kb, 500kb, and 1Mb. The device does not contain a termination resistor in the standard product but can be added upon request.

Auto Baud Rate Detection

The device will remain in listen only mode until it has detected the baud rate per J1939-16 requirements. While detecting the baud rate, the device will scan each of the supported baud rates for 1.5 seconds to determine if there are any messages on the CAN bus. The baud rate will be detected on first power up and then will be retained in non-volatile memory for faster subsequent baud detection and data transmission. The first baud rate tested will be the known baud rate. If the known baud rate is not detected, all baud rates will be scanned.

CAN Network Interface

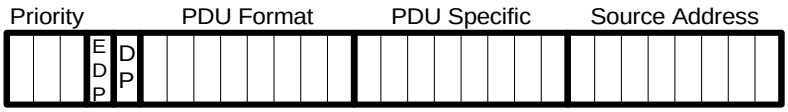
The device will comply with the following network interfaces:

- CAN 2.0b Physical Bus / J1939 Superset
- ISO 11898 physical layer (Copper media)
- Primary Network Interface

All network interfaces will meet all environmental specifications and be isolated to the maximum extent practical.

J1939 Extended Frame Format

J1939 uses the 29-bit extended frame format identifier.



The 29 identifier bits are defined as follows:

- Extended Data Page (EDP) is zero.
- Data Page (DP) is zero.
- Proprietary PDU1 Format (PF) is 239 (0xEF) for point-to-point messages (J1939-21)
- Proprietary PDU1 Format (PF) is 255 (0xFF) for broadcast messages. (J1939-21)
- PDU Specific (PS) is the Destination Address (DA) for point-to-point messages.
- PDU Specific (PS) is zero for broadcast messages.
- The Source Address (SA), is the Node Address (SAE J1939-21) of the message source.

Dual-Axis Mode CAN Message

This is the angle information message sent when the device is in dual-axis mode. This message is sent from the device.

Slope Sensor Information

The 'Slope Sensor Information' message transmits the device's pitch and roll data. This message is sent by each of the sensors when the device is in 'Dual-Axis' mode.

PGN 61459 (0xF013)
Priority 0x03
Source Address 0xE2, 0xE3, 0xEA (Default)
CAN ID 0x0CF013E2, 0x0CF013E3, 0x0CF013EA
Repetition Rate 10ms (Default. This can be changed using the 'Sensor Data Transmit Interval' setting)

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6				BYTE 7
						b0-1	b2-3	b4-5	b6-7	
Pitch Angle		Roll Angle		Pitch Rate		PAF	RAF	PRF	PRC	Meas. Latency

Start Position	Name	Description
0	Pitch Angle	The angle between the vehicle's y-axis and the ground plane (i.e. rotation about the vehicle's x-axis). Byte 1 is the most significant byte. SPN 3318 Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg
2	Roll Angle	The angle between the vehicle x-axis and the ground plane (i.e. rotation about the y-axis). Byte 3 is the most significant byte. SPN 3319 Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg
4	Pitch Rate	Pitch rate is the rate-of-change of the pitch angle over time, where the pitch angle vector is in the direction of travel of the vehicle. Byte 5 is the most significant byte. SPN 3322 Data Length 2 bytes Resolution 0.002deg/sec-bit Offset -64 deg Data Range -64 to 64.51deg/sec
6.0	Pitch Angle	Figure of merit for pitch angle measurement.

	Figure of Merit	SPN 3323 Data Length 2 bits Resolution: 4 states/2-bit Configuration: 00 Pitch Angle fully functional. Data is within sensor specification. 01 Pitch Angle degraded. Data is suspect due to environmental conditions. 10 Error 11 Not available
6.2	Roll Angle Figure of Merit	Figure of merit for roll angle measurement. SPN 3324 Data Length 2 bits Resolution: 4 states/2-bit Configuration: 00 Roll Angle fully functional. Data is within sensor specification. 01 Roll Angle degraded. Data is suspect due to environmental conditions. 10 Error 11 Not available
6.4	Pitch Rate Figure of Merit	Figure of merit for the pitch rate measurement. SPN 3325 Data Length 2 bits Resolution: 4 states/2-bit Configuration: 00 Pitch Rate fully functional. Data is within sensor specification. 01 Pitch Rate degraded. Data is suspect due to environmental conditions. 10 Error 11 Not available
6.6	Pitch and Roll Compensated	Compensated mode for the pitch and roll measurements. Compensation is the use of multiple sensors together to enhance the output of pitch and roll measurements. SPN 3326 Data Length 2 bits Resolution: 4 states/2-bit Configuration: 00 Compensation Off 01 Compensation On 10 Error 11 Not Available
7	Pitch and Roll Measurement Latency	The estimated latency of the measurement. SPN 3327 Data Length 1 byte Resolution 0.5 ms/bit Offset 0 ms Data Range 0 to 125 ms

Single-Axis Mode CAN Message

This is the angle information message sent when the device is in single-axis mode. This message is sent from the device.

Blade Information (Ladder Angle)

The 'Blade Information' message transmits the device's blade angle data. This message is sent by each of the sensors when the device is in 'Single-Axis' mode.

PGN 61460 (0xF014)
Priority 0x03
Source Address 0xE2, 0xE3, 0xEA (Default)
CAN ID 0x0CF014E2, 0x0CF014E3, 0x0CF014EA
Repetition Rate 10ms (Default This can be changed using the 'Sensor Data Transmit Interval' setting)

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5			BYTE 6	BYTE 7
					b0-1	b2-3	b4-7		
Relative Blade Height		Blade Rotation Angle		Latency	HFM	FAM	R	Reserved	

Start Position	Name	Description
0	Relative Blade Height	The measured vertical distance from a fixed location on the machine blade to a ground-based reference (i.e. relative height). Note: This feature is not currently used. Byte 1 is the most significant byte. SPN 3365 Data Length 2 bytes Resolution 0.1 mm/bit Offset -3,200 mm Data Range -3,200 to 3,225.5 mm
2	Blade Rotation Angle	The blade rotation angle measurement around the yaw (z-axis). Byte 3 is the most significant byte. SPN 3331 Data Length 2 bytes Resolution 1/128 deg/bit Offset -200 deg Data Range -180 to 180 deg
4	Measurement Latency	The estimated latency of the measurement. SPN 3366 Data Length 1 byte Resolution 0.5 ms/bit Offset 0 Data Range 0 to 125 ms

5.0	Relative Blade Height Figure of Merit	Figure of merit for blade height measurement. Note: This feature is not currently used. SPN 3367 Data Length 2 bits Resolution: 4 states/2-bit Configuration: 00 Relative Blade Height fully functional. 01 Relative Blade Height degraded. 10 Relative Blade Height failed. 11 Relative Blade Height not available
5.2	Blade Rotation Angle Figure of Merit	Figure of merit for blade rotation measurement. SPN 3332 Data Length 2 bits Resolution: 4 states/2 bits Configuration: 00 Blade Rotation Angle fully functional. Data is within sensor specification. 01 Blade Rotation Angle degraded. Data is suspect due to environmental conditions. 10 Blade Rotation Angle failed. Roll sensor failed to operate correctly. 11 Blade Rotation Angle not available
5.4	Reserved	Reserved Data Length 4 bits
6	Reserved	Reserved Data Length 2 bytes

Standard Device Can Messages

These are the messages that come standard on all devices. These messages are sent by the device.

Acknowledge Command

The acknowledge command message is a response to a command message. It is sent whenever the unit receives a valid command message.

PGN 65468 (0xFFBC)
Priority 0x03
Source Address 0xE2, 0xE3, 0xEA (Default)
CAN ID 0x18FFBCE2, 0x18FFBCE3, 0x18FFBCEA
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Acknowledge Data							

Start Position	Name	Parameter Name
0	Acknowledge Data	The 'acknowledge data' is an echo of the data from the message received. This identifies the messages that is being acknowledged. Data Length 8 Bytes

Revision and Serial Number

The 'Revision and Serial Number' messages transmits the revision and serial number of the device. This message is transmitted in response to the 'Data Request' message.

PGN 61185 (0x00EF01)
Priority 0x06
Source Address 0xE2, 0xE3, 0xEA (Default)
CAN ID 0x18EF01E2, 0x18EF01E3, 0x18EF01EA
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Revision	Serial Number				Reserved		

Start Position	Name	Description
0	Revision	The source code revision of the device. This value is transmitted in ASCII. Data Length 1 Byte Data Range 0x41 to 0x5A (ASCII A to ASCII Z)
1	Serial Number	The serial number of the device. Data Length 4 bytes Resolution 1 Offset 0 Data Range 0 to 0xFFFFFFFE
5	Reserved	Reserved Data Length 3 Bytes

Stored Settings Data

The 'Stored Settings Data' messages transmits the device's stored settings. This message is transmitted in response to the 'Data Request' message.

PGN 61186 (0x00EF02)
Priority 0x06
Source Address 0xE2, 0xE3, 0xEA (Default)
CAN ID 0x18EF02E2, 0x18EF02E3, 0x18EF02EA
Repetition Rate N/A

BYTE 0				BYTE 1			BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
b0-1	b2-3	b4-5	b6-7	b0-2	b3-5	b6-7						
SPP	SRP	SO	SVF	SVP	SST	R	Stored Sample Size	Stored Acc Increment	Reserved			

Start Position	Name	Description
0.0	Stored Pitch Polarity	The stored polarity of the pitch rotation. The default is CCW = positive. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 N/A 1 CCW = Positive, CW = Negative 2 CCW = Negative, CW =Positive 3 N/A
0.2	Stored Roll Polarity	The stored polarity of the roll rotation. The default is CCW = positive. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 N/A 1 CCW = Positive, CW = Negative 2 CCW = Negative, CW =Positive 3 N/A
0.4	Stored Pitch and Roll Orientation	The stored pitch and roll axis orientation. This is either the standard orientation (pitch about the x-axis, roll about the y-axis), or the switched orientation (pitch about the y-axis, roll about the x-axis). The default is standard orientation. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 N/A 1 Standard Orientation (pitch about the x-axis, roll about the y-axis) 2 Switched Orientation (pitch about the y-axis, roll about the x-axis) 0 N/A

0.6	Stored Vibe Filter	The stored vibration filter setting. The default is noise block mode. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 N/A 1 Low Noise Mode 2 Noise Block Mode 3 N/A
1.0	Stored Vertical Plane	The stored vertical plane of the device. This is the axis perpendicular to the ground when the device is at zero. The default is the Z-Plane Data Length 3 bit Resolution 7 states / 3 bit Configuration: 0 N/A 1 Z-Plane 2 X-Plane 3 Y-Plane 4 Negative Z-Plane 5 Negative X-Plane 6 Negative Y-Plane 7 N/A
1.3	Stored Sensor Data Transmitted	The stored selection for which sensors are currently transmitting the 'Slope Sensor Information' message. Data Length 3 bit Resolution 7 states / 3 bit Configuration: 0 N/A 1 Transmit All Data (Sensor and Compensated) 2 Transmit Only Compensated Data 3 Transmit Only Sensor Data 4 Transmit Only A Single Sensor's Data 5 N/A 6 N/A 7 N/A
1.6	Reserved	Reserved Data Length 2 bits
2	Stored Sample Size	The stored number of measurements that are averaged together when calculating the angle. The default is 20. Data Length 1 Byte Resolution 1 sample/bit Offset 0 Data Range 1 To 20

3	Stored Accelerometer Increment	The stored value for the percentage at which the accelerometer angle is added to the reported angle. The default is 1%. Data Length 1 Byte Resolution 0.1%/bit Offset 0 Data Range 0.1% to 10%
4	Reserved	Reserved Data Length 4 Bytes

Stored Offsets Data

The 'Stored Offsets Data' messages transmits the device's stored user and zero offsets. This message is transmitted in response to the 'Data Request' message.

PGN 61187 (0x00EF03)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF03E2, 0x18EF03E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Stored User Pitch Offset		Stored User Roll Offset		Stored Zero Pitch Offset		Stored Zero Roll Offset	

Start Position	Name	Description
0	Stored User Pitch Offset	The stored adjustment to the pitch offset. This value is expressed as a 16-bit word in two's compliment. Byte 1 is the most significant. Data Length 2 bytes Resolution 0.002 deg/bit Offset 0 deg Data Range -65.634 to 65.534
2	Stored User Roll Offset	The stored adjustment to the roll offset (Note: the roll offset is used for the blade angle as well). This value is expressed as a 16-bit word in two's compliment. Byte 3 is the most significant. Data Length 2 bytes (Signed) Resolution 0.002 deg/bit Offset 0 deg Data Range -65.634 to 65.534
4	Stored Zero Pitch Offset	The stored user set offset used to zero the pitch angle. Byte 5 is the most significant byte. Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg
6	Stored Zero Roll Offset	The stored user set offset used to zero the roll angle. Byte 7 is the most significant byte. Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg

Additional Device CAN Messages

These are additional messages that come with certain variants of the device. These messages are sent by the device.

Raw Acceleration Data

The 'Raw Acceleration Data' messages transmits the linear acceleration data from the sensor. This message is transmitted in response to the 'Data Request' message.

PGN 61188 (0x00EF04)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF04E2, 0x18EF04E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Raw X Acc.		Raw Y Acc		Raw Z Acc		Reserved	

Start Position	Name	Description
0	Raw X Acceleration	The linear acceleration sensor's raw x-axis value. Byte 1 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
2	Raw Y Acceleration	The linear acceleration sensor's raw y-axis value. Byte 3 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
4	Raw Z Acceleration	The linear acceleration sensor's raw z-axis value. Byte 5 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
6	Reserved	Reserved Data Length 2 Bytes

Raw Gyroscope Data

The 'Raw Gyroscope Data' messages transmits the angular rate data from the sensor. This message is transmitted in response to the 'Data Request' message.

PGN 61189 (0x00EF05)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF05E2, 0x18EF05E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Raw Gyro. Pitch		Raw Gyro. Roll		Raw Gyro. Yaw		Reserved	

Start Position	Name	Description
0	Raw Gyro. Pitch	The angular rate sensor's pitch axis (X) value. Byte 1 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 35mdps/bit Offset 0 Data Range -1000dps to 1000dps
2	Raw Gyro. Roll	The angular rate sensor's roll axis (Y) value. Byte 3 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1000dps to 1000dps
4	Raw Gyro. Yaw	The angular rate sensor's yaw axis (Z) value. Byte 5 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1000dps to 1000dps
6	Reserved	Reserved Data Length 2 Bytes

Temperature Data

The 'Temperature Data' messages transmits the temperature data from the sensor. This message is transmitted in response to the 'Data Request' message.

PGN 61190 (0x00EF06)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF06E2, 0x18EF06E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Raw Temperature		Reserved					

Start Position	Name	Description
0	Raw Temperature	The sensor's temperature data. Byte 1 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.0039°C/bit Offset 25°C Data Range -102.996°C to 152.996°C
2	Reserved	Reserved Data Length 6 Bytes

Accelerometer Angle Data

The 'Accelerometer Angle Data' messages transmits the angle calculated using only the linear acceleration data from the sensor. This message is transmitted in response to the 'Data Request' message.

PGN 61191 (0x00EF07)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF07E2, 0x18EF07E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Acc. Pitch Angle		Acc. Pitch Angle		Reserved			

Start Position	Name	Description
0	Accelerometer Pitch Angle	The accelerometer angle between the vehicle's y-axis and the ground plane (i.e. rotation about the vehicle's x-axis). Byte 1 is the most significant byte. Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg
2	Accelerometer Roll Angle	The accelerometer angle between the vehicle x-axis and the ground plane (i.e. rotation about the y-axis). Byte 3 is the most significant byte. Data Length 2 bytes Resolution 0.002deg/bit Offset -64 deg Data Range -64 to 64.51deg
6	Reserved	Reserved Data Length 4 Bytes

Calibrated Acceleration Data

The 'Calibrated Acceleration Data' messages transmits the calibrated linear acceleration data. This message is transmitted in response to the 'Data Request' message.

PGN 61192 (0x00EF08)
Priority 0x06
Source Address 0xE2, 0xE3 (Default)
CAN ID 0x18EF08E2, 0x18EF08E3
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Cal. X Acc.		Cal. Y Acc		Cal. Z Acc		Reserved	

Start Position	Name	Description
0	Cal. X Acceleration	The linear acceleration sensor's calibrated x-axis value. Byte 1 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
2	Cal. Y Acceleration	The linear acceleration sensor's calibrated y-axis value. Byte 3 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
4	Cal. Z Acceleration	The linear acceleration sensor's calibrated z-axis value. Byte 5 is the most significant byte. This value is expressed as a 16-bit word in two's compliment. Data Length 2 bytes Resolution 0.061mg/bit Offset 0 Data Range -1.99885g to 1.99885g
6	Reserved	Reserved Data Length 2 Bytes

Standard Controller CAN Messages

The controller CAN messages are the messages sent to the device to configure or request data from the device.

Service Mode Enable Command

The 'Service Mode Enable' messages will put the selected sensor into service mode. Once a sensor is in service mode it can accept configurations messages. Service mode is off by default. Note: Turning the device off will cause it to exit service mode.

PGN 65456 (0x00FFB0)
Priority 0x03 (Note: Any priority will be accepted)
Source Address 0x00 (Note: Any source address will be accepted)
CAN ID 0x0CFFB000
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
	0x2A	0xE7	0x4D	0x9B			
Sensor Address	Service Mode Enable/Disable				Reserved		

Start Position	Name	Description
0	Sensor Address	The address of the sensor in which service mode is being enabled / disabled. Data Length 1 Byte Data Range 0 to 254
1	Service Mode Enable / Disable	The value is the passcode needed to place the unit into service mode. Any value other than the passcode will take the unit out of service mode. Byte 4 is the most significant byte. Data Length 4 Bytes Resolution 2 states / 4 Byte Configuration: 0x9B4DE72A Service Mode Enabled All others values Service Mode Disabled
5	Reserved	Reserved Data Length 3 Bytes

Sensor Address Command

The 'Sensor Address' message will set the source address of the selected sensor. The selected address cannot already be assigned to a different sensor. The device must be in service mode to receive this message.

PGN 65457 (0x00FFB1)
Priority 0x03 (Note: Any priority will be accepted)
Source Address 0x00 (Note: Any source address will be accepted)
CAN ID 0x0CFFB100
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Sensor Address	New Sensor Address	Reserved					

Start Position	Name	Description
0	Sensor Address	The address of the sensor whose address is being changed. Data Length 1 Byte Data Range 0 to 254
1	New Sensor Address	The new address for the selected sensor. The address selected cannot be in use by another sensor. Data Length 1 Byte Data Range 0 to 254
2	Reserved	Reserved Data Length 6 Bytes

Sensor Offset Adjustment Command

The 'Sensor Offset Adjustment' message allows the manual adjustment of the selected sensor's pitch and roll value. The adjusted value is added to the measured value that the sensor reports. A positive value increases the offset. The device must be in service mode to receive this message. Note: these values are cleared when the device is zeroed.

PGN 65458 (0x00FFB2)
Priority 0x03 (Note: Any priority will be accepted)
Source Address 0x00 (Note: Any source address will be accepted)
CAN ID 0x0CFFB200
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
Sensor Address	Pitch Offset Adjustment		Roll Offset Adjustment		Reserved		

Start Position	Name	Description
0	Sensor Address	The address of the sensor whose offset is being adjusted. Data Length 1 Byte Data Range 0 to 254
1	Pitch Offset Adjustment	The adjustment to the pitch offset. This value is expressed as a 16-bit word in two's compliment. Byte 2 is the most significant. Data Length 2 bytes Resolution 0.002 deg/bit Offset 0 deg Data Range -65.634 to 65.534
3	Roll Offset Adjustment	The adjustment to the roll offset (Note: the roll offset is used for the blade angle as well). This value is expressed as a 16-bit word in two's compliment. Byte 4 is the most significant. Data Length 2 bytes Resolution 0.002 deg/bit Offset 0 deg Data Range -65.634 to 65.534
5	Reserved	Reserved Data Length 3 Bytes

Device Settings Command

The 'Device Settings' message allows the user to configure the device settings. Note: this message will change the settings of the device, not just the individual sensors. The device must be in service mode to receive this message.

PGN 65459 (0x00FFB3)
Priority 0x03 (Note: Any priority will be accepted)
Source Address 0x00 (Note: Any source address will be accepted)
CAN ID 0x0CFFB300
Repetition Rate N/A

BYTE 0	BYTE 1	BYTE 2				BYTE 3				BYTE 4			B5	B6	B7
		b0-1	b2-3	b4-5	b6-7	b0-1	b2-3	b4-5	b6-7	b0-2	b3-4	b5-7			
Sensor Address	Sample Size	ZS	DV	CO	CZ	AM	PP	RP	OR	VP	VF	ST	TX Int.	Acc Incr.	R

Start Position	Name	Parameter Name
0	Sensor Address	The address of either of the two sensors must be specified. This is to ensure the correct device is changed if there is more than one device on the CAN bus. Data Length 1 Byte Data Range 0 to 254
1	Sample Size	The number of measurements that are averaged together when calculating the angle. Each new measurement replaces the oldest measurement. The default is 20. Data Length 1 Byte Resolution 1 sample/bit Offset 0 Data Range 1 To 20
2.0	Zero Sensors	Set the current position of the device as zero for the pitch and roll. Data Length 2 bit Resolution 2 states / 2 bit Configuration: 0 Do Nothing 1 Zero Sensors 2 Do Nothing 3 Do Nothing
2.2	Detect Vertical Plane	Automatically detect and set the vertical plane of the device. This will detect the current direction of the ground (depending on how the device is mounted) and set the z-axis accordingly. Data Length 2 bit Resolution 2 states / 2 bit Configuration: 0 Do Nothing

		1 Detect Horizontal Plane 2 Do Nothing 3 Do Nothing
2.4	Clear Offset Adjustment	Set the user defined pitch and roll offset adjustments to zero. Data Length 2 bit Resolution 2 states / 2 bit Configuration: 0 Do Nothing 1 Clear the user offset 2 Do Nothing 3 Do Nothing
2.6	Clear Zero Offset	Clear the offset that was used to zero the device. Data Length 2 bit Resolution 2 states / 2 bit Configuration: 0 Do Nothing 1 Clear the zero offset 2 Do Nothing 3 Do Nothing
3.0	Axis Mode	Set the device to either 'Dual-Axis' or 'Single-Axis' mode. In dual-axis mode, the device will transmit the pitch and roll angle. In single-axis mode the device will transmit the blade angle. The default is dual-axis mode. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 No Change 1 Dual-Axis Mode (Pitch and Roll Angle) 2 Single-Axis Mode (Blade Angle) 3 No Change
3.2	Pitch Polarity	Set the positive and negative direction of the pitch rotation. The default is CCW = positive. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 No Change 1 CCW = Positive, CW = Negative 2 CCW = Negative, CW =Positive 3 No Change
3.4	Roll Polarity	Set the positive and negative direction of the roll rotation. The default is CCW = positive. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 No Change

		1 CCW = Positive, CW = Negative 2 CCW = Negative, CW =Positive 3 No Change
3.6	Pitch and Roll Orientation	Set the pitch and roll axis orientation. This is either the standard orientation (pitch about the x-axis, roll about the y-axis), or the switched orientation (pitch about the y-axis, roll about the x-axis). The default is standard orientation. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 No Change 1 Standard Orientation (pitch about the x-axis, roll about the y-axis) 2 Switched Orientation (pitch about the y-axis, roll about the x-axis) 0 No Change
4.0	Vertical Plane	Manually set the vertical plane of the device. This is the axis perpendicular to the ground when the device is at zero. The default is the Z-Plane Data Length 3 bit Resolution 7 states / 3 bit Configuration: 0 Do Nothing 1 Z-Plane 2 X-Plane 3 Y-Plane 4 Negative Z-Plane 5 Negative X-Plane 6 Negative Y-Plane 7 Do Nothing
4.3	Vibe Filter	Set the device to either 'Low Noise' or 'Noise Block' mode. In low noise mode, when vibrational noise is detected the percentage at which the accelerometer is added to the reported angle is set to 0.01%. In noise block mode, the accelerometer angle is ignored when vibrational noise is detected. The default is noise block mode. Data Length 2 bit Resolution 3 states / 2 bit Configuration: 0 No Change 1 Low Noise Mode 2 Noise Block Mode 3 No Change
4.5	Sensor Data Transmitted	The sensors which are currently transmitting the 'Slope Sensor Information' message. Data Length 3 bit Resolution 7 states / 7 bit Configuration: 0 Do Nothing 1 Transmit All Data (Sensor and Compensated) 2 Transmit Only Compensated Data

		3 Transmit Only Sensor Data 4 Transmit Only A Single Sensor's Data 5 Do Nothing 6 Do Nothing 7 Do Nothing
5	Transmit Interval	The interval at which the inclinometer data is transmitted. The default is 10ms. Data Length 1 Byte Resolution 10ms/bit Offset 0 Data Range 10ms to 2500ms
6	Acc Increment	The percentage at which the accelerometer angle is added to the reported angle. A higher value will increase the rate of change. A lower value will increase noise rejection. The default is 1%. Data Length 1 Byte Resolution 0.1%/bit Offset 0 Data Range 0.1% to 10%
7	Reserved	Reserved Data Length 1 Bytes

Data Request Command

The 'Data Request' message allows the user to request data from the device. Any data requested will be sent a single time per request. Data can be requested at any time.

PGN 65460 (0x00FFB4)
Priority 0x03 (Note: Any priority will be accepted)
Source Address 0x00 (Note: Any source address will be accepted)
CAN ID 0x0CFFB400
Repetition Rate N/A

BYTE 0	BYTE 1								BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
	b0	b1	b2	b3	b4	b5	b6	b7						
Sensor Address	RR	SR	OR	AR	GR	TR	AA	CR	Reserved					

Start Position	Name	Parameter Name
0	Sensor Address	The address of the sensors whose data is being requested. Data Length 1 Byte Data Range 0 to 254
1.0	Revision Request	Set the device to transmit the "Revision and Serial Number" message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.1	Stored Settings Request	Set the device to transmit the "Stored Settings Data" message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.2	Stored Offsets Request	Set the device to transmit the "Stored Offsets Data" message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.3	Raw Accel. Request	Set the device to transmit the "Raw Acceleration Data" message once. Data Length 1 bit Resolution 2 states / 1 bit

		Configuration: 0 Do Nothing 1 Transmit Requested Message
1.4	Raw Gyro. Request	Set the device to transmit the “Raw Gyroscope Data” message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.5	Temp. Request	Set the device to transmit the “Temperature Data” message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.6	Acc. Angle Request	Set the device to transmit the “Accelerometer Angle Data” message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
1.7	Calibrated Accel. Request	Set the device to transmit the “Calibrated Acceleration Data” message once. Data Length 1 bit Resolution 2 states / 1 bit Configuration: 0 Do Nothing 1 Transmit Requested Message
2	Reserved	Reserved Data Length 6 Bytes